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(71) Applicant: SANDVIK AKTIEBOLAG
811 81 Sandviken (SE)

(72) Inventors:
- Olsson, Björn
141 71 Huddinge (SE)
- Ljungberg, Björn
122 44 Enskede (SE)

(74) Representative: Östlund, Alf Olof Anders et al
Sandvik AB
Patent Department
811 81 Sandviken (SE)

(54) **Coated cutting insert**

(57) The present invention discloses a coated cutting insert particularly useful for dry milling of grey cast iron. The insert is characterized by a WC-Co cemented carbide substrate and a coating including an innermost layer of $TiC_xN_yO_z$ with columnar grains and a top coating of a fine-grained α-Al_2O_3 layer.

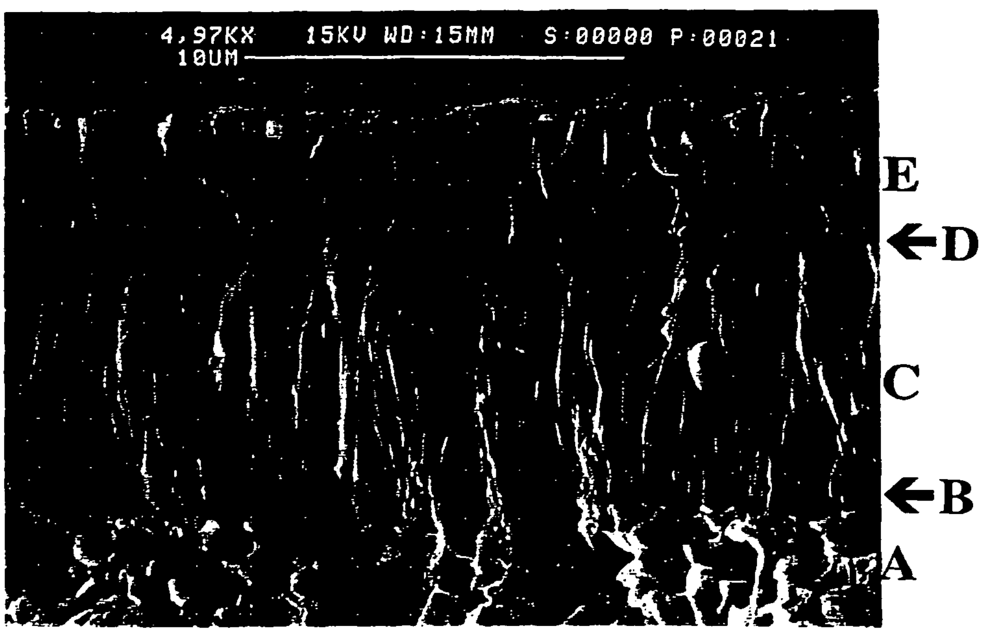

Fig. 1

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Description

The present invention relates to a coated cutting tool (cemented carbide insert) particularly useful for dry milling of grey cast iron.

Grey cast-iron is a material which, in general, is reasonably easy to machine with cemented carbide tools. Often, long tool life can be obtained. However, the machinability of cast iron can vary considerably. The tool life may be influenced significantly by small variations in the chemical composition within the material which may be related to the casting technique used, such as the cooling conditions. Other causes for variations are the casting skin and sand inclusions, if present, or even the stability of the machine used for cutting the material. It is well-known that the machinability of a cast iron may vary from one batch to another.

There is always a desire for a reliable and stable tool life in mass volume production and in particular when unmanned production is employed.

When machining grey cast iron by coated milling cutters, the cutters are worn mainly by a so called adhesive wear mechanism. That is, fragments or individual grains of the layers and later also parts of the cemented carbide are successively pulled away from the cutting edge by the work piece chip formed. Such wear mechanism is further accelerated by the formation of cracks about 50 µm apart along and perpendicular to the cutting edge generally referred to as comb cracks. They are the result of thermal fatigue caused by the intermittent cutting which is typical for all milling cutting operations. Commercial cemented carbide milling inserts therefore generally contain gamma-phase, which is a solid solution of WC-TiC-TaC-NbC, in order to decrease heat influenced wear mechanism.

As soon as the coating is worn out, the underlying cemented carbide will wear fast. This will lead to higher cutting forces. The comb cracks formed will, after some time, cause severe chipping of the cutting edge and the damaged tool will generate a bad surface or chipping of the machined component.

Chipforming operations predominantly of adhesive wear type put high demands on both the coating and the cemented carbide. A cemented carbide that can withstand comb crack formation as long as possible and a coating that adheres well to the cemented carbide is desirable. Further, it is desired that there are low adhesion forces between the chip and the coating and that the coating has a high internal strength (cohesiveness) a property which is believed to be of significant importance.

It has surprisingly been found that a straight WC-Co cemented carbide body herein referred to as the substrate essentially provided with a first/inner columnar grained coating structure consisting of mainly a $TiC_xN_yO_z$-layer with columnar grains and a columnar like textured fine-grained α-Al_2O_3 layer on top performs very well particularly in cast iron milling. In fact such a tool has been found to have a cutting performance far better than prior art tools.

Fig 1 is a micrograph in 5000X magnification of a coated insert according to the present invention in which

A - substrate
B - $TiC_xN_yO_z$-layer with equiaxed grains
C - $TiC_xN_yO_z$-layer with columnar grains
D - $Tic_xN_yO_z$-Fayer with equiaxed or needlelike grains
E - (012)-textured α-Al_2O_3-Fayer with columnar like grains

According to the present invention a cutting tool insert is provided of a cemented carbide substrate of a WC+Co composition containing 3-15, preferably 5-12, most preferably 5-8 wt-% Co, and with a WC grain size of 1-2 µm, preferably about 1.5 µm. In addition, the substrate may contain up to 2 wt-% cubic carbides of metals from groups IVb, Vb or VIb of the periodic table such as TiC, TaC and NbC. However, a straight WC+Co composition is preferred.

The coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, preferably z<0.5, with a thickness of 0.1-2 µm, and with equiaxed grains with size <0.5 µm
- a next layer of $TiC_xN_yO_z$ x+y+z=1, preferably with z=0 and x>0.3 and y>0.3, with a thickness of 2-10 µm, preferably 4-7 µm, with columnar grains and with a diameter of about <5 µm, preferably <2 µm
- a next layer of $TiC_xN_yO_z$, x+y+z=1 with z≤0.5, preferably z>0.1, with a thickness of 0.1-2 µm and with equiaxed or needlelike grains with size ≤0.5 µm, this layer being the same as or different from the innermost layer, and
- an outer layer of a smooth, textured, fine-grained (grain size about 1 µm) α-Al_2O_3 layer with a thickness of 2-10 µm, preferably 3-6 µm, and a surface roughness (R_a) of less than 0.3 mm over a measured length of 0.25 mm. Preferably, this Al_2O_3-Fayer is the outermost layer but it may also be followed by further layers such as a thin (about 0.1 - 1 µm) decorative layer of e g TiN as is known in the art.

In addition, the α-Al_2O_3 layer has a preferred crystal growth orientation in either the (012)-, (104)- or (110)-direction, preferably in the (012)-direction, as determined by X-ray Diffraction (XRD) measurements. A Texture Coefficient, TC,

is defined as:

$$TC(hkl) = \frac{I(hkl)}{I_o(hkl)} \left\{\frac{1}{n} \sum \frac{I(hkl)}{I_o(hkl)}\right\}^{-1}$$

where

I(hkl) = measured intensity of the (hkl) reflection
I_o(hkl) = standard intensity of the ASTM standard powder pattern diffraction data
n = number of reflections used in the calculation, (hkl) reflections used are: (012), (104), (110), (113), (024), (116)

According to the invention TC for the set of (012), (104) or (110) crystal planes is larger than 1.3, preferably larger than 1.5.

According to method of the invention a WC-Co-based substrate is coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, preferably z<0.5, with a thickness of 0.1-2 µm, and with equiaxed grains with size <0.5 µm using known CVD-methods.
- a next layer of $TiC_xN_yO_z$ x+y+z=1, preferably with z=0 and x>0.3 and y>0.3, with a thickness of 2-10 µm, preferably 4-7 µm, with columnar grains and with a diameter of about <5 µm, preferably <2 µm, deposited either by MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700-900 °C) or by high temperature CVD-technique (1000-1100 °C), the process conditions being selected to grow layers with columnar grains, that is generally high process pressure (0.3-1 bar). However, the exact conditions depend to a certain extent on the design of the equipment used.
- a next layer of $TiC_xN_yO_z$, x+y+z=1 with z≤0.5, preferably z>0.1, with a thickness of 0.1-2 µm and with equiaxed or needlelike grains with size ≤0.5 µm, using known CVD-methods this layer being the same as or different from the innermost layer.
- an outer layer of a smooth textured α-Al_2O_3 layer with a thickness of 2-10 µm, preferably 3-6 µm, and a surface roughness (R_a) of less than 0.3 µm over a measured length of 0.25 mm according to Swedish patent 501 527 or Swedish patent applications 9304283-6 or 9400089-0.

When a $TiC_xN_yO_z$-layer with z>0 is desired, CO_2 and/or CO is added to the reaction gas mixture.

Example 1

A) Cemented carbide milling inserts of style TNEF1204AN-65 and of style SEKN1204AZ with the composition 6 % Co and balance WC were coated with a 0.5 µm equiaxed TiCN-layer followed by a 5 µm thick TiCN layer with columnar grains by using MTCVD-technique (process temperature 850 °C). In subsequent process steps during the same coating cycle, a 1 µm thick layer with equiaxed grains of $TiC_xN_yO_z$ (approx. x=0.6, y=0.2 and z=0.2) was deposited followed by a 4 µm thick layer of (012)-textured α-Al_2O_3 deposited according to conditions given in Swedish patent 501 527. XRD-measurement showed a texture coefficient TC(012) of 1.5. After coating the inserts were smoothed by wet blasting.

B) Cemented carbide milling inserts of style TNEF1204AN-65 were coated with a 1 µm layer with equiaxed grains of TiCN followed by 5 µm thick layer of columnar grains of a TiCN by high temperature CVD-technique (1020 °C, process pressure 400 mbar).

In subsequent process steps during the same coating cycle, a 1 µm thick layer with equiaxed grains of $TiC_xN_yO_z$ (approx. x=0.6, y=0.2 and z=0.2) was deposited followed by a 4 µm thick layer of (012)-textured α-Al_2O_3 deposited according to conditions given in Swedish patent 501 527. XRD-measurement showed a texture coefficient TC(012) of 1.6. After coating the inserts were smoothed by wet blasting.

C) Cemented carbide milling cutting inserts of style TNEF 1204AN-65 with the composition 5.5 % Co and 8.5 % cubic carbides and balance WC were coated under the procedure given in A). After coating the inserts were smoothed by wet blasting.

D) Milling inserts from the same cemented carbide batch as in C) were coated with equiaxed 5 µm TiCN-coating and 4 µm Al_2O_3 carried out according to prior art technique resulting in a mixture of coarse α- and fine K-Al_2O_3 grains in the layer. The inserts were smoothed by wet blasting.

Example 2

Inserts from A) were tested against two competitor grades as below:

Operation: Face milling with SANDVIK AUTO cutter, dia: 250 mm
Workpiece: Specially designed component.
Material: SS0125 (grey cast iron HB=205)
Cutting speed: 129 m/min
Feed rate: 0.24 mm/tooth
Depth of cut: 2.0 mm
Insert-type: TNEF1204AN-65
Note: The operation was run without coolant (dry).

RESULTS:	Tool-life, min
Grade A (according to invention)	40
Competitor 1 (prior art)	20
Competitor 2 (prior art)	25

Tool-life criterion was chipping on the exit side of the workpiece.

Example 3

Inserts from A) were tested in another milling operation against two other competitors grades as below:

Operation: Face milling with SANDVIK 145-cutter, dia: 63 mm.
Workpiece: Hydraulic engine component
Material: SS0125 (grey cast iron HB=220)
Cutting speed: 178 m/min
Feed rate: 0.17 mm/tooth
Depth of cut: 2-3 mm
Insert-type: SEKN1204AZ
Note: The operation was run without coolant (dry).

RESULTS:	Tool-life, hours
Grade A (invention)	24
Competitor 3 (prior art)	15
Competitor 4 (prior art)	16

Tool-life criterion was surface finish.

Example 4

Inserts from A), C) and D) were tested against each other in a milling operation

Operation: Face milling with SANDVIK AUTO cutter, diameter 250 mm.
Workpiece: Engine block
Material: SS0125 (GG26Cr) grey cast iron
Cutting speed: 120 m/min
Feed rate: 0.28 mm/tooth
Depth of cut: 4-5 mm
Insert-type: TNEF1204AN-65
Note: The operation was run without coolant (dry).

The inserts were all run 868 passes and compared with respect to edge chipping.

Results:	Variant	Degree of edge chipping
	A (invention)	none
	C (only improved coating)	minor
	D (prior art)	severe

The results show the benefit of the coating according to the invention as well as combining this with the WC/Co-carbide substrate in order to achieve maximum performance.

Example 5

Inserts from A), B) and D) were tested against each other in a milling operation.

Operation: Face milling with SANDVIK AUTO cutter, diameter 250 mm.
Workpiece: Special designed test component
Material: SS0125 grey cast iron, HB= 205
Cutting speed: 129 m/min
Feed rate: 0.30 mm/tooth
Depth of cut: 2 mm
Insert-type: TNEF1204AN-65
Note: The operation was run without coolant (dry).

The inserts were all run 48 passes and compared with respect to edge chipping.

Results:	Variant	Relation width of chipped area
	A (invention)	0.3
	B (invention)	0.4
	D (prior art)	1.0

The results show in practise equal performance of A) and B). The only difference is the coating temperature used when depositing the TiCN-layers. The prior art inserts show highest wear.

Claims

1. Cutting insert for milling of grey cast iron comprising a substrate and a coating **characterised** in that said substrate consists of WC, 3-15 weight-% Co and ≤2 weight-% carbides of metals from groups IVb, Vb or VIb of the periodic table and in that said coating comprises

   - a first (innermost) layer of $TiC_xN_yO_z$ with a thickness of 0.1-2 μm, and with equiaxed grains with size <0.5 μm
   - a layer of $TiC_xN_yO_z$ with a thickness of 2-10 μm with columnar grains with a diameter of about <5 μm
   - a layer of $TiC_xN_yO_z$ with a thickness of 0.1-2 μm and with equiaxed or needlelike grains with size ≤0.5 μm
   - an outer layer of a smooth, textured, fine-grained α-Al_2O_3 layer with a thickness of 2-10 μm

2. Cutting insert according to the preceding claim **characterised** in that the α-Al_2O_3 layer has a texture in (012)-direction and with a texture coefficient TC(012) larger than 1.3.

3. Cutting insert according to claim 1 **characterised** in that the a-Al_2O_3 layer has a texture in the (104)-direction and with a texture coefficient TC(104) larger than 1.3.

4. Cutting insert according to claim 1 **characterised** in that the α-Al_2O_3 layer has a texture in (110)-direction and with a texture coefficient TC(110) larger than 1.3.

5. Cutting insert according to the preceding claims **characterised** in an outermost coating of a thin 0.1-1 μm TiN-layer.

6. Method of making a cutting insert comprising a substrate and a coating **characterised** in that WC-Co-based sub-

strate is coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with a thickness of 0.1-2 μm, with equiaxed grains with size <0.5 μm using known CVD-methods
- a layer of $TiC_xN_yO_z$ with a thickness of 2-10 μm with columnar grains and with a diameter of about <5 μm deposited either by MTCVD-technique, using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700-900 °C, or by high temperature CVD-technique
- a layer of $TiC_xN_yO_z$ with a thickness of 0.1-2 μm with equiaxed or needlelike grains with size ≤0.5 μm, using known CVD-methods
- an outer layer of a smooth textured α-Al_2O_3 layer with a thickness of 2-10 μm according to known CVD-technique.

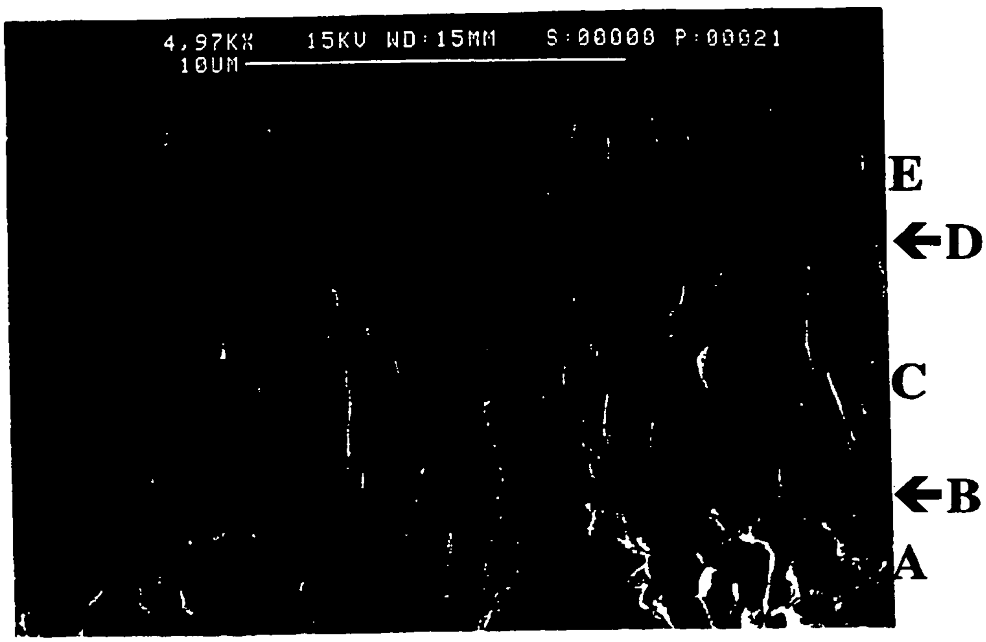

Fig. 1

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(71) Applicant: **SANDVIK AKTIEBOLAG**
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(72) Inventors:
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Sandvik AB
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(54) **Coated cutting insert**

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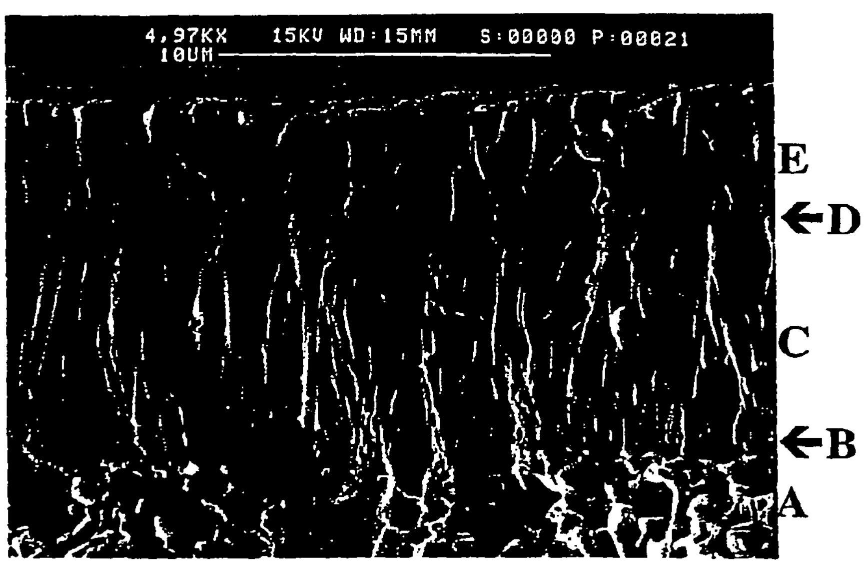

Fig. 1

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EUROPEAN SEARCH REPORT

Application Number
EP 96 85 0054

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP-A-0 600 115 (MITSUBISHI MATERIALS CORP) 8 June 1994 * claims 1,3-5; tables 1,2 * ---	1-6	C23C30/00
E	EP-A-0 709 484 (MITSUBISHI MATERIALS CORP) 1 May 1996 * claims 1-5,7; tables 3,5 * -----	6	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			C23C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 January 1997	Flink, E

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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